US009359892B2

(12) United States Patent
Tao

(10) **Patent No.: US 9,359,892 B2**
(45) **Date of Patent: Jun. 7, 2016**

(54) **SPRING ASSISTED ACTIVE MUD CHECK VALVE WITH SPRING**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 524 days.

(21) Appl. No.: **13/803,065**

(22) Filed: **Mar. 14, 2013**

(65) **Prior Publication Data**

US 2014/0158228 A1 Jun. 12, 2014

Related U.S. Application Data

(60) Provisional application No. 61/734,694, filed on Dec. 7, 2012.

(51) **Int. Cl.**
E21B 34/10 (2006.01)
E21B 49/08 (2006.01)

(52) **U.S. Cl.**
CPC ***E21B 49/081*** (2013.01); ***E21B 34/10*** (2013.01); *Y10T 137/7838* (2015.04); *Y10T 137/86815* (2015.04)

(58) **Field of Classification Search**
CPC Y10T 137/86815
See application file for complete search history.

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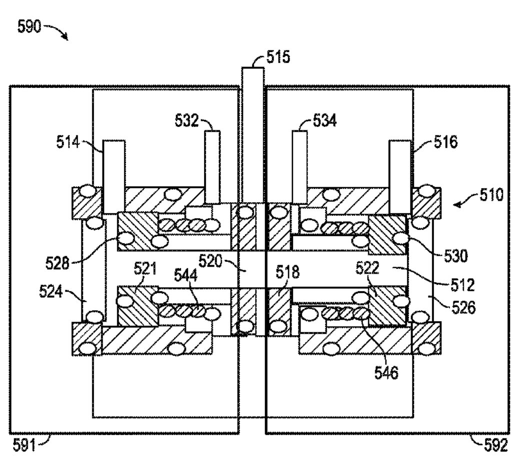
(57) **ABSTRACT**

An apparatus, a method and a system control fluid flow through a passageway. A downhole tool pumping apparatus may have a body and an active valve block. The body has a cavity housing a reciprocating piston defining first and second chambers within the cavity. The active valve block has active valves configured to be actively actuated between an open position and the closed position. Two or more hydraulic lines may be connected to each active valve for controlling actuating between the open position and the closed position. A piston having a conduit is slidably disposed through the passageway and selectively closes the conduit of the piston by moving at least one of the piston and a plug.

8 Claims, 9 Drawing Sheets



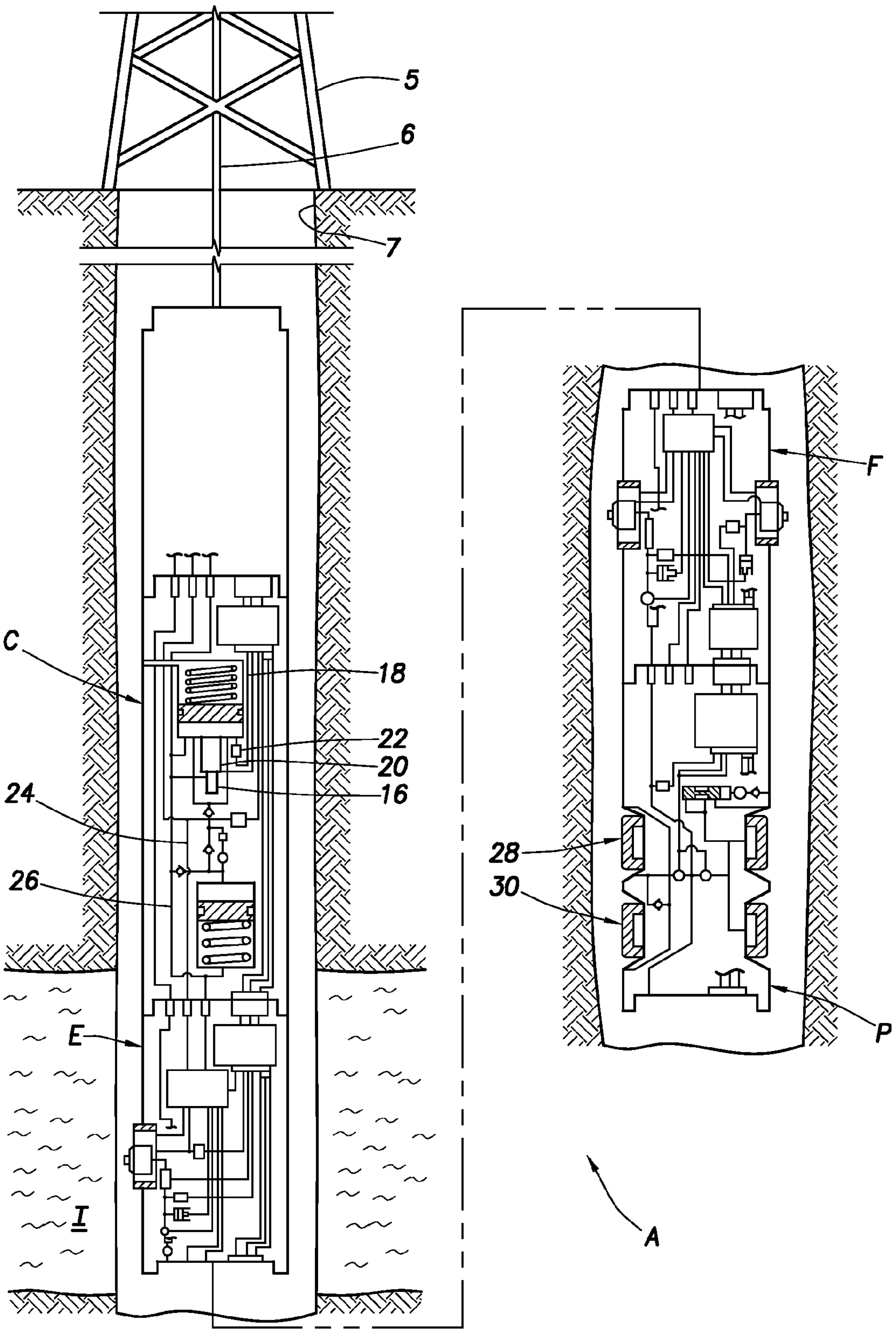


FIG. 1
(PRIOR ART)

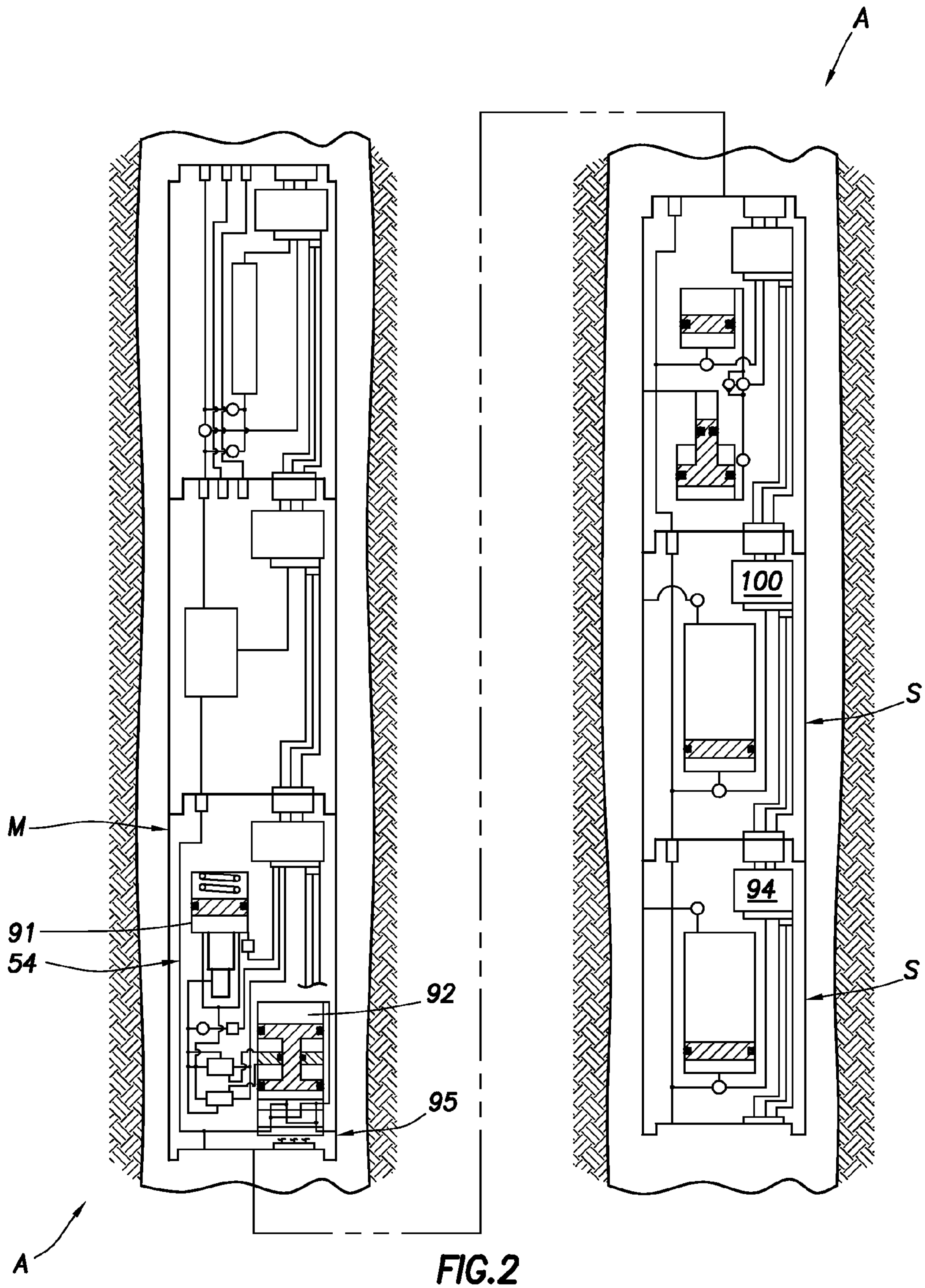


FIG.2
(PRIOR ART)

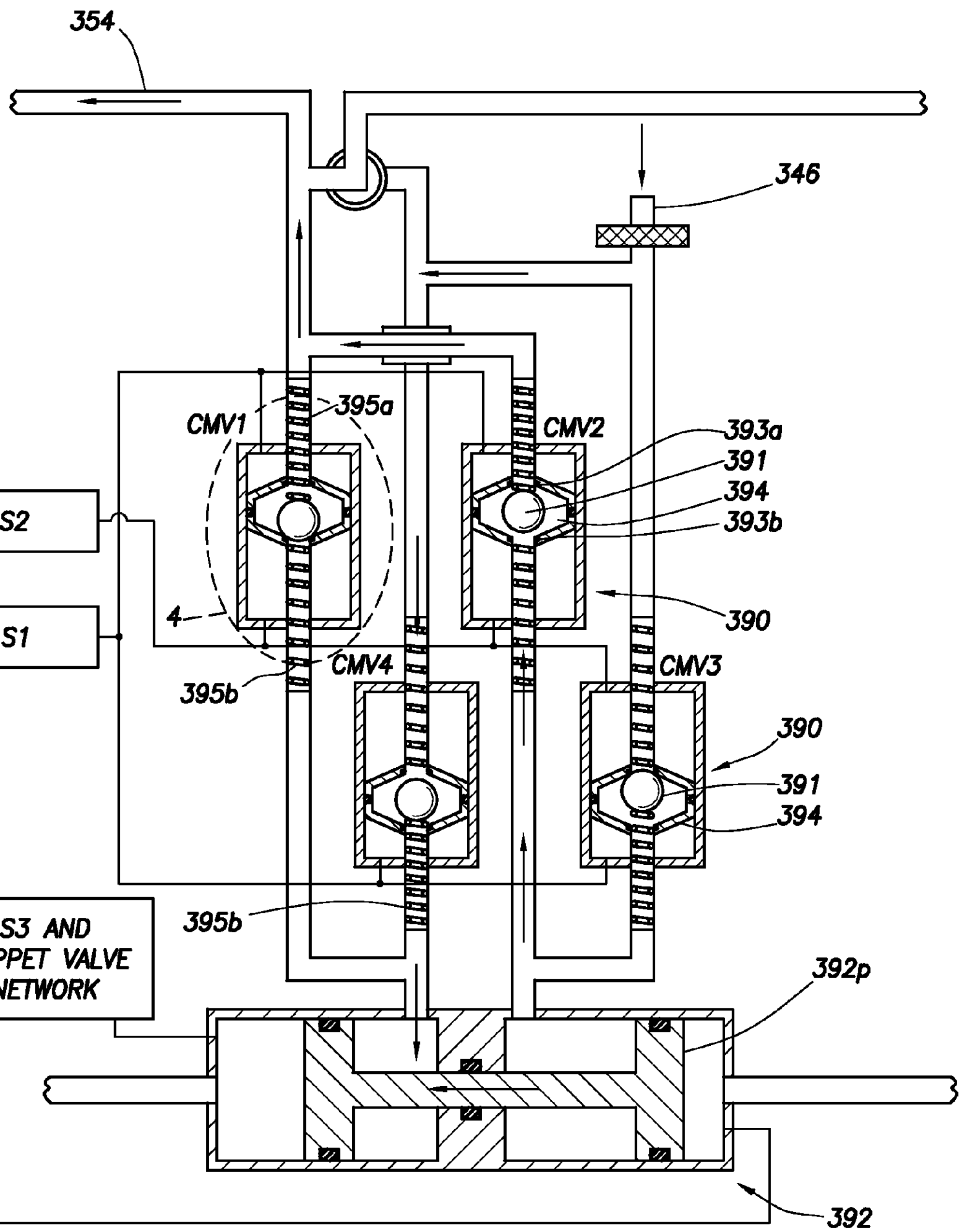


FIG.3A
(PRIOR ART)

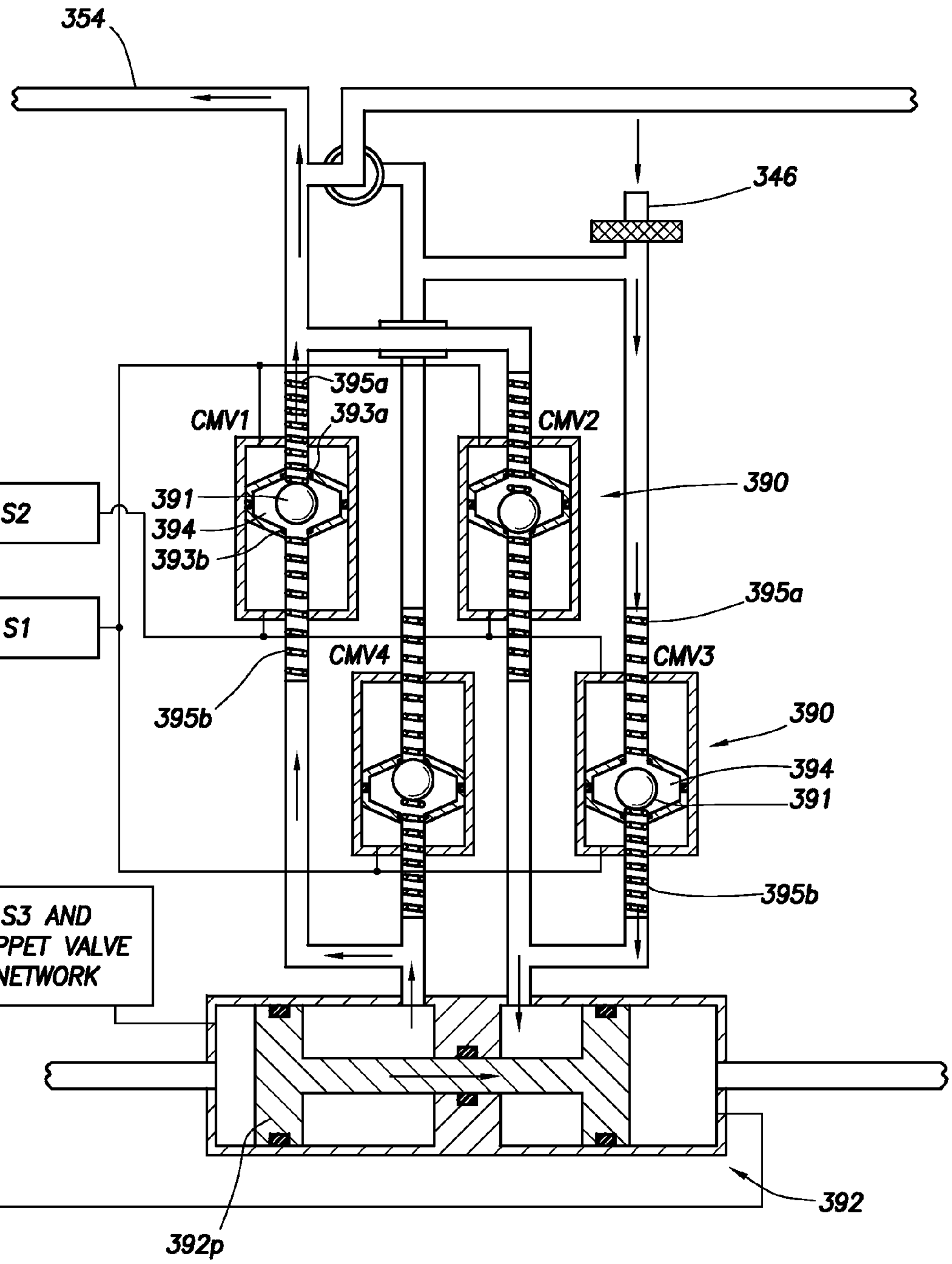


FIG.3B
(PRIOR ART)

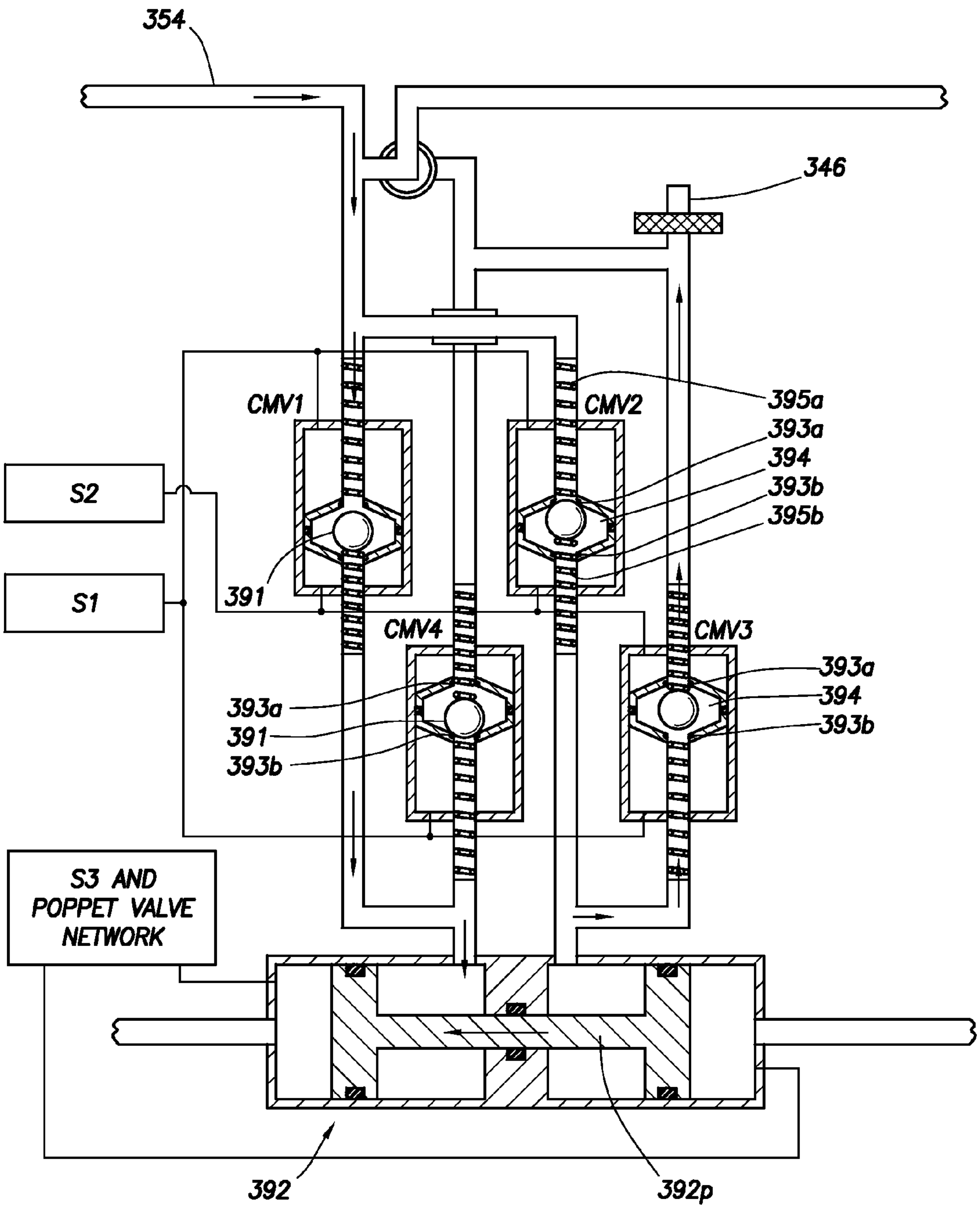


FIG.4A
(PRIOR ART)

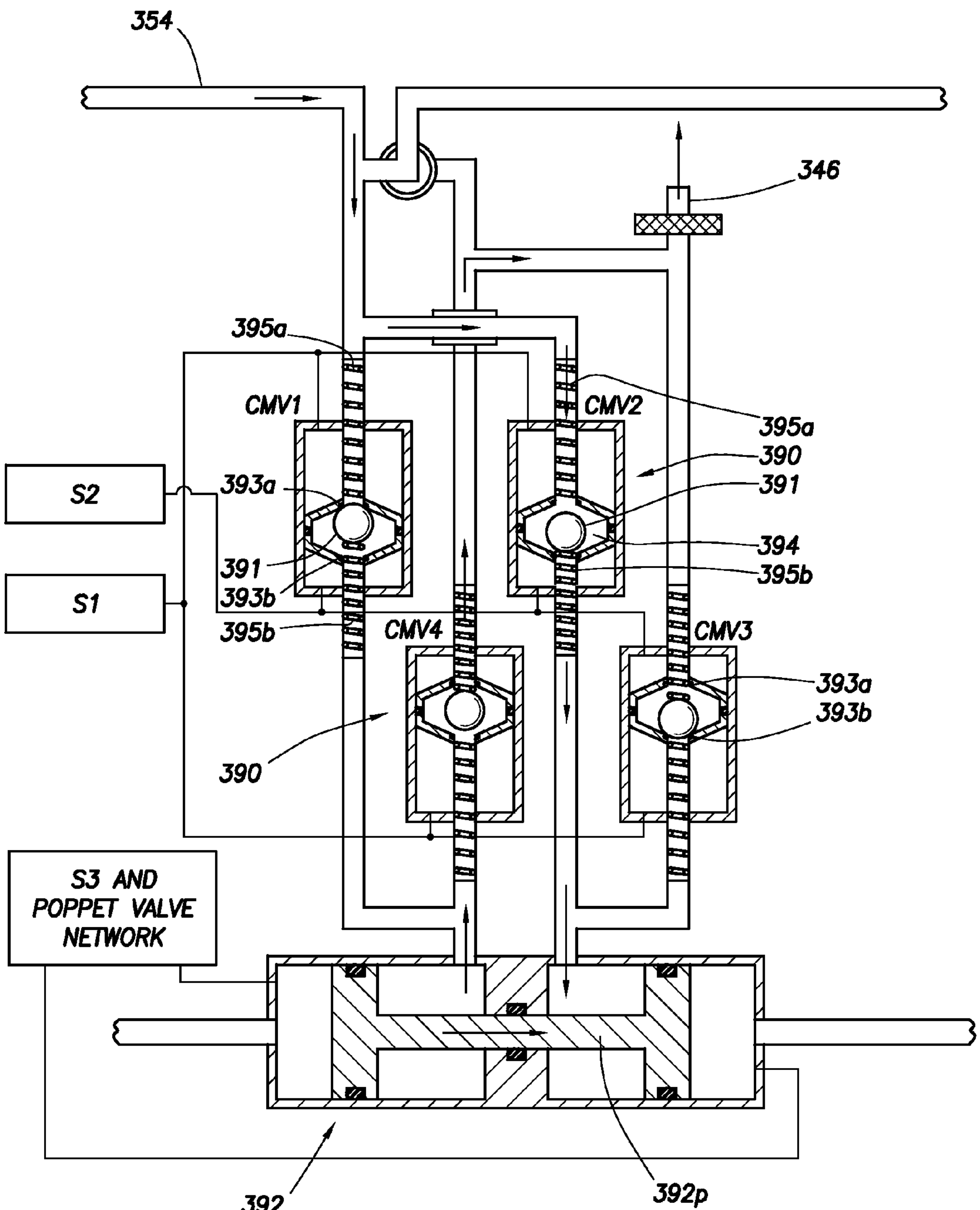


FIG.4B
(PRIOR ART)

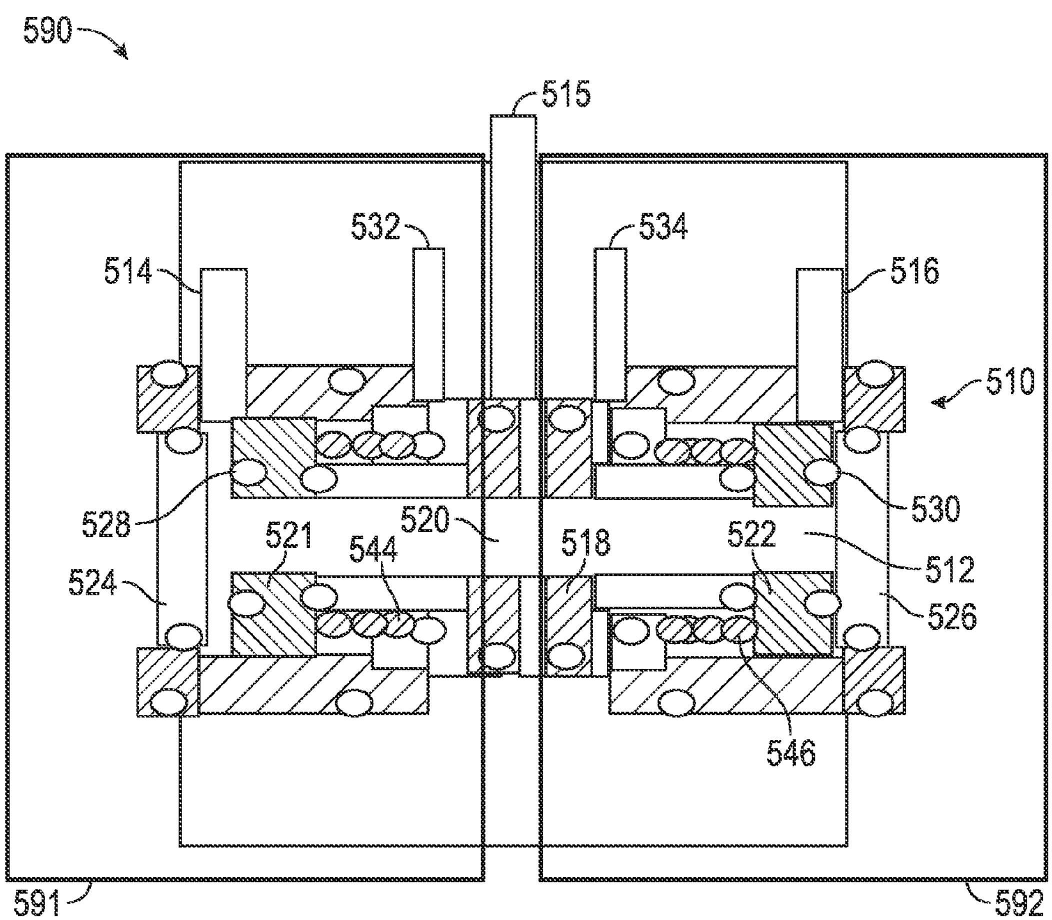

590
515
532
534
514
516
510
528
530
520
518
522
512
521
544
524
526
546
591
592

FIG. 5A

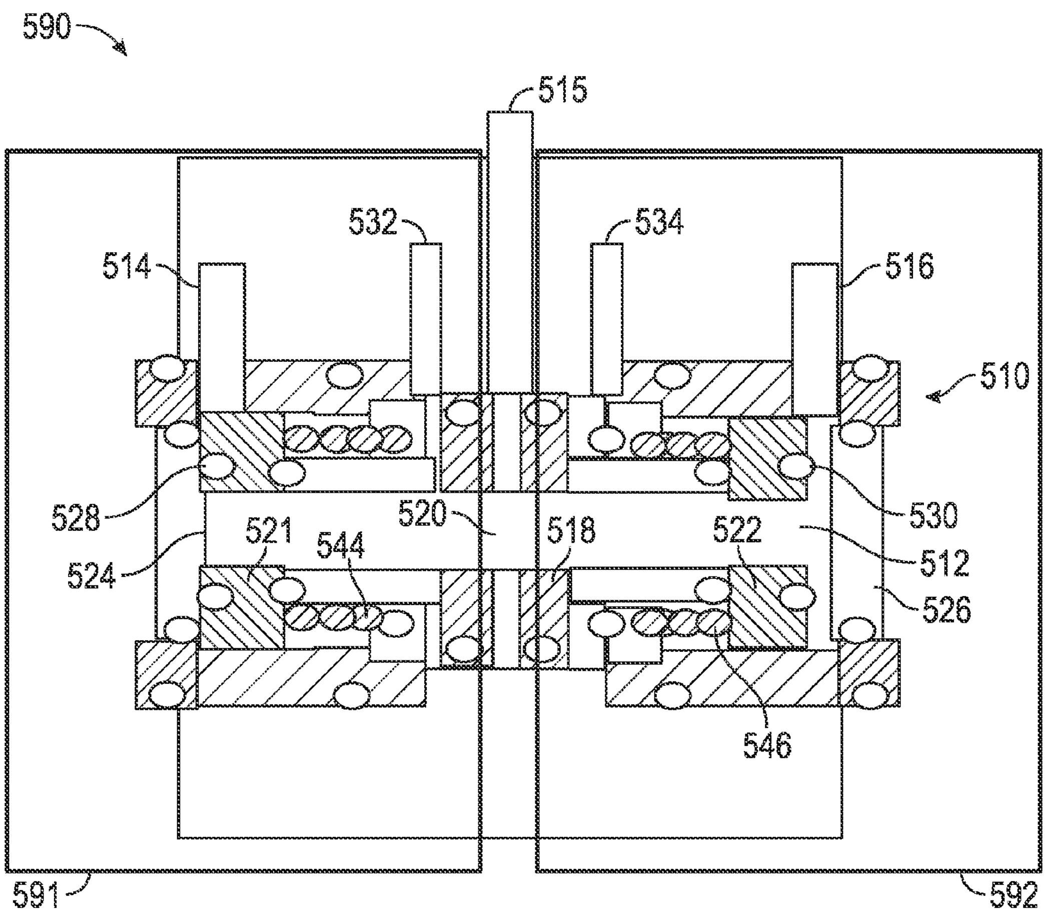

590
515
532
534
514
516
510
528
530
520
518
522
521
544
512
524
526
546
591
592

FIG. 5B

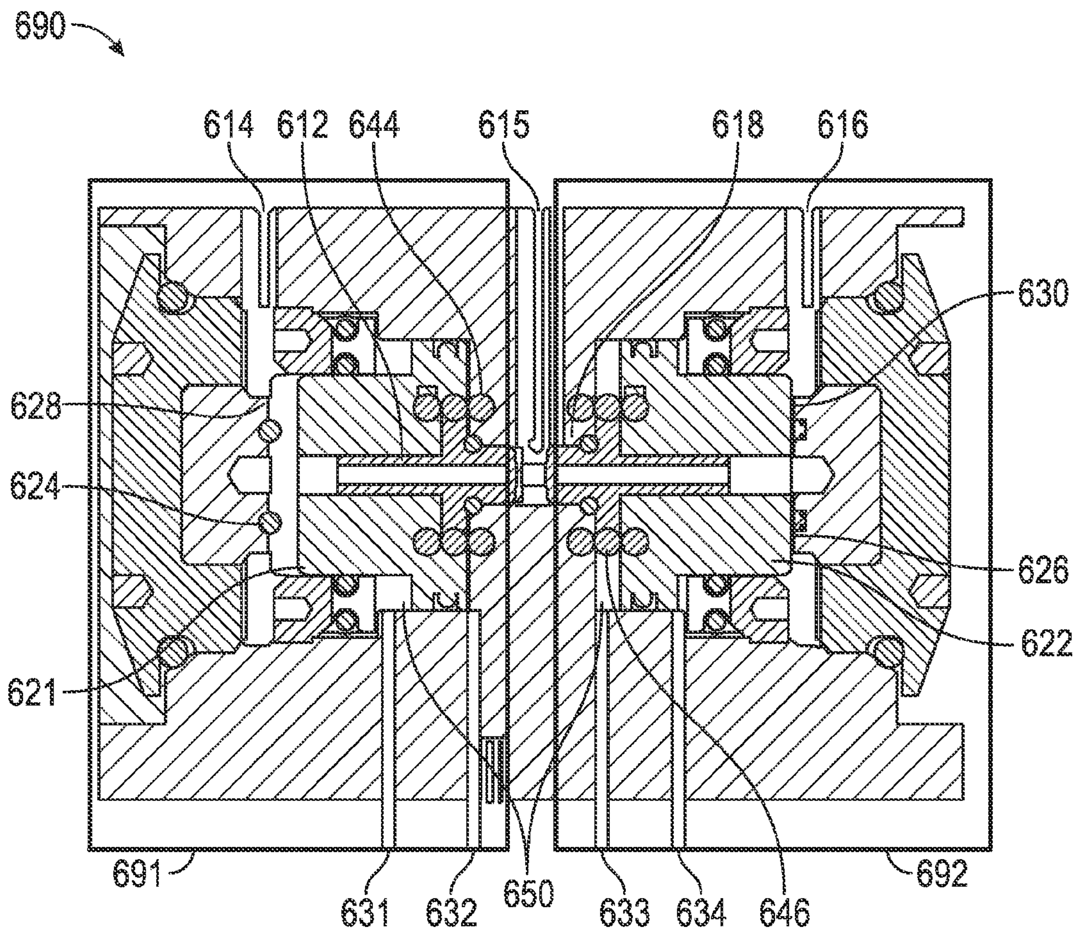

690
614
612
644
615
618
616
630
628
624
626
622
621
691
631
632
650
633
634
646
692

FIG. 6

SPRING ASSISTED ACTIVE MUD CHECK VALVE WITH SPRING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application 61/734,694 filed Dec. 7, 2012, the entirety of which is incorporated herein by reference.

FIELD OF THE INVENTION

Aspects of the present disclosure generally relate to fluid flow control. More specifically, aspects of the present disclosure relate to controlling the flow of fluid such as formation fluid and/or borehole fluid within a downhole tool.

BACKGROUND INFORMATION

Underground formation testing is performed during drilling and geotechnical investigation of underground formations. The testing of such underground formations is important as the results of such examinations may determine, for example, if a driller proceeds with drilling and/or extraction. Since drilling operations are expensive on a per day basis, excessive drilling impacts the overall economic viability of drilling projects.

Multi-valve well testing tools use multiple valves configured in a circuit. Toggling of one of the valves typically sets the other valves into motion as well. The well testing tools disclosed in U.S. Pat. No. 4,553,598 to Meek entitled "Full Bore Sampler Valve Apparatus", and in U.S. Pat. No. 4,576,234 to Upchurch entitled "Full Bore Sampler Valve", are mechanical in nature. One valve is disposed in the tool and is mechanically linked to another valve disposed in the tool. To open one valve, an operator at the well surface, upon opening the valve, must expect the other valve to open or close, since the two valves are mechanically linked together. Therefore, the operation of one valve is not independent of the operation of the other valve. When one valve in the tool is opened, other valves disposed in the tool must be opened or closed in a specific predetermined sequence.

More recent multi-valve well testing tools use other arrangements for toggling valves. For example, semi-passive valves are referenced in U.S. Pat. No. 7,527,070 to Brennan, III et al., the entirety of which is incorporated herein by reference. Brennan, III et al. disclose valves that are partially passive wherein the flow of fluid through the valve assists in toggling the valve. Hydraulics are only used in the referenced system to assist in returning the valve-state to its original position. The hydraulic valve systems of the prior art do not use hydraulics to initially set the valve or valves into motion. Moreover, the valve systems are not fully active. That is, all aspects of valve movement are not controlled by hydraulics. To provide a valve system that is fully active, a solenoid is required for each individual valve. Space is limited in a downhole tool, and each solenoid requires a relatively large amount of space.

Therefore, a need exists for providing a system and/or method that uses hydraulic pressure to toggle valve state while minimizing size and/or the number of solenoids required.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1** and **2** are schematic views of a prior art wireline-conveyed downhole tool with which one or more aspects of the present disclosure may be used.

FIGS. **3**A, **3**B, **4**A and **4**B are schematic views of a prior art fluid pumping system.

FIGS. **5**A and **5**B show an active mud check valve with two hydraulic lines in accordance with one or more aspects of the present disclosure.

FIG. **6** shows an active mud check valve with four hydraulic lines in accordance with one or more aspects of the present disclosure.

DETAILED DESCRIPTION

Certain examples are shown in the above-identified figures and described in detail below. In describing these examples, like or identical reference numbers are used to identify common or similar elements. The figures are not necessarily to scale and certain features and certain views of the figures may be shown exaggerated in scale or in schematic for clarity and/or conciseness.

The example valves described herein may be used on a downhole tool to sample fluids in a subterranean formation. More specifically, the example valves described herein may route dirty fluid between the displacement unit and inlet or outlet flowline portions of a testing tool.

FIGS. **1** and **2** illustrate a prior art downhole tool which may be suspended from a rig **5** by a wireline **6** and lowered into a well bore **7** for the purpose of evaluating surrounding formations I. Details relating to tool A are described in U.S. Pat. Nos. 4,860,581 and 4,936,139, both to Zimmerman et al., the entireties of which are hereby incorporated by reference. The downhole tool A has a hydraulic power module C, a packer module P, and a probe module E. The hydraulic power module C includes a pump **16**, a reservoir **18**, and a motor **20** which controls operation of the pump **16**. A low oil switch **22** also forms part of the control system and is used to regulate the operation of the pump **16**.

The hydraulic fluid line **24** is connected to the discharge of the pump **16** and runs through hydraulic power module C and into adjacent modules for use as a hydraulic power source. In the embodiment shown in FIG. **1**, the hydraulic fluid line **24** extends through the hydraulic power module C into the probe modules E and/or F depending upon which configuration is used. The hydraulic loop is closed by virtue of the hydraulic fluid return line **26**. As shown in FIG. **1**, the hydraulic fluid return line **26** extends from the probe module E to the hydraulic power module C where the hydraulic fluid return line **26** terminates at the reservoir **18**.

The tool A further includes a pump-out module M, as shown in FIG. **2**, which can be used to dispose of unwanted samples by pumping fluid through the flow line **54** into the borehole, or may be used to pump fluids from the borehole into the flow line **54** to inflate the straddle packers **28** and **30**, as shown in FIG. **1**. Furthermore, the pump-out module M may be used to draw formation fluid from the borehole via the probe module E or F, and then pump the formation fluid into the sample chamber module S against a buffer fluid therein. In other words, the pump-out module may be used for pumping fluids into, out of, and through the downhole tool A.

A piston pump **92**, energized by hydraulic fluid from a pump **91**, may be aligned in various configurations, e.g., to draw from the flowline **54** and dispose of the unwanted sample though flowline **95**. Alternatively, the pump **92** may be aligned to pump fluid from the borehole into the flowline **54**. The pump-out module M can also be configured where the flowline **95** connects to the flowline **54** such that fluid may be drawn from the downstream portion of the flowline **54** and pumped upstream or vice versa. The pump-out module M has the necessary control devices to regulate the piston pump **92** and to align the fluid line **54** with the fluid line **95** to accomplish the pump-out procedure.

Referring to FIGS. **3**A, **3**B, **4**A and **4**B, a particular embodiment of the pump-out module M may use four reversible mud check valves **390**, also referred to as CMV**1**-CMV**4**, to direct the flow of the fluid being pumped. These reversible mud check valves **390** allow the pump-out module M to pump either up or down, or in or out, depending on the tool configuration. The reversible mud check valves **390** may utilize a spring-loaded ceramic ball **391** that seals alternately on one of two O-ring seats **393***a*, **393***b* to allow fluid flow in only one direction. The O-ring seats **393***a*, **393***b* are mounted in a sliding piston-cylinder **394**, also called a check valve slide or a piston slide.

FIGS. **3**A and **3**B show the respective first stroke and second stroke of the two-stroke operation of the piston pump **392** with the pump-out module M configured to "pump-in" mode, where fluid is drawn into the module M through a port **346** for communication via a flowline **354**. Thus, the solenoids SI, S**2** are energized in FIGS. **3**A and **3**B to direct hydraulic fluid pressure to shift the piston slides **394** of the check valves CMV**1** and CMV**2** upwardly and shift the piston slides **394** of the check valves CMV**3** and CMV**4** downwardly. The fluid pressure causes the upper springs **395***a* of the check valves CMV**1** and CMV**2** to bias the respective balls **391** against the lower seal seats **393***b*, and the lower springs **395***b* of check valves CMV**3** and CMV**4** to bias the respective balls **391** against the upper seal seats **393***a*. The biasing of the balls **391** allows fluid to flow upwardly through the check valve CMV**2** and downwardly through the check valve CMV**4** under movement of the piston **392***p* to the left, as indicated by the directional arrows of FIG. **3**A. Similarly, the biasing of the balls **391** allows fluid to flow upwardly through the check valve CMV**1** and downwardly through valve CMV**3** under movement of the piston **392***p* to the right, as indicated by the directional arrows of FIG. **3**B. Sufficient fluid-flowing pressure may be needed to overcome the respective spring-biasing forces. Solenoid S**3** is provided to selectively move the pump piston **392***p* from the position in FIG. **3**A to the position in FIG. **3**B and back. The solenoid S**3** may also be linked to solenoids S**1** and S**2** to synchronize the timing therebetween.

FIGS. **4**A and **4**B show a respective first stroke and second stroke of the two-stroke operation of the piston pump **392** with the pump-out module M configured to "pump-out" mode, where fluid is discharged from the flowline **354** through the port **346** into the borehole. Thus, the solenoids S**1**, S**2** have been de-energized in FIGS. **4**A and **4**B to direct hydraulic pressure to shift the piston slides **394** of the check valves CMV**1** and CMV**2** downwardly and shift the piston slides **394** of the check valves CMV**3** and CMV**4** upwardly. This shifting results in the lower springs **395***b* of the check valves CMV**1** and CMV**2** biasing the respective balls **391** against the upper seal seats **393***a*. Further, the shifting results in the upper springs **395***a* of the check valves CMV**3** and CMV**4** biasing the respective balls **391** against the lower seal seats **393***b*. The biasing of the balls **391** allows fluid to flow downwardly through the check valve CMV**1** and upwardly through the check valve CMV**3** under movement of the pump piston **392***p* to the left, as indicated by the directional arrows of FIG. **4**A. Similarly, the biasing of the balls **391** allows fluid to flow downwardly through the check valve CMV**2** and upwardly through the check valve CMV**4** under movement of the pump piston **392***p* to the right, as indicated by the directional arrows of FIG. **4**B. Sufficient fluid-flowing pressure may be needed to overcome the respective spring-biasing forces.

In each of the FIGS. **3**A, **3**B, **4**A and **4**B, the check valves having no directional flow arrows are configured such that their respective balls **391** are subjected to fluid pressure that compresses each ball against an o-ring seat to maintain a seal. Conversely, when the direction of fluid flow opposes the spring-biasing forces, a gap is opened between the ball and the seat so as to permit the fluid flow indicated by the three directional arrows. The valves open to balance the pressure differential across the opening with the biasing forces provided by the respective springs.

The fluid pumped through the tool A, flows directly past the o-ring seats **393***a*, **393***b* at various intervals during the two-stroke pumping cycles. Since this fluid may be formation fluid or borehole fluid laden with impurities varying from fine mud particles to abrasive debris of various sorts, such flow may produce accelerated wear of the o-ring seats. The wear can shorten the life of the o-ring and may lead to frequent failure of the seals. The following are examples of failures that may occur: 1) the o-ring is gradually worn during the pumping process until the o-ring will no longer seal; 2) debris gets trapped between the ball and one or both of the O-ring seats; 3) fine particles settle in the valve cavity and may gradually build up to the point where the particles prevent the ball from sealing against the seat; and 4) filters that are typically used with such valves are susceptible to plugging. The failure of any one of the four reversible mud check valve seals may reduce the output of the pump **392**, and the loss of two seals may completely disable the pump **392**.

The present disclosure illustrates a system and method for pumping formation fluid through a downhole tool using controlled mud check valves. The system and/or method may use one or more springs to assist in opening and closing the valves. The mud check valves may operate using only hydraulic pressure with the assistance of the springs. Furthermore, a reduced number of solenoids are required to open and close the valves.

In accordance with the present disclosure, a valve **590** is described to exhibit a non-limiting example of an embodiment of the application. Referring now to the drawings wherein like numerals refer to like parts, FIGS. **5**A and **5**B show schematic views of a flow control valve **590** in respective closed and open positions according to one or more aspects of the present disclosure.

The valve **590** combines two mud check valves **591**, **592** in one port, thus saving tool space and reducing flowline dead volume. The valve **590** may be used as a check valve, e.g., as a replacement for the check valve CMV**1** (also referenced as **390**) of FIGS. **3**A, **3**B, **4**A and **4**B within a downhole tool, such as tool A of FIGS. **1** and **2**. The downhole tool is adapted for use in a borehole environment. Accordingly, the check valve **590** includes a body **510** having a fluid passageway **512** therethrough and a first flowline **514** and a second flowline **516**. Each of the flowlines **514**, **516** is adapted for receiving or discharging fluid from the passageway **512**. The first flowline **514** may communicate fluid with another portion of the tool, such as, for example, a lower module of the tool. The second flowline **516** may communicate fluid with another portion of the tool, such as, for example, an upper module of the tool. A third flowline **515** may be provided extending from the valve **590**. The third flowline **515** may be in communication with a displacement unit, such as the displacement unit **392** shown in FIGS. **3**A, **3**B, **4**A and **4**B.

A piston **518** may be slidably disposed in the passageway **512** between the first flowline **514** and the second flowline **516** of the body **510**. The piston **518** may have a conduit portion **520** that defines a bore therethrough for conducting fluid through the passageway **512**. The piston **518** may have the third flowline **515** extending therefrom. The piston **518** may also be referred to as a sliding cylinder, a check valve slide, or simply a piston slide.

A pair of annular seals **528**, **530** may seal the first flowline **514** and the second flowline **516**, respectively. The annular seals **528**, **530** may be elastomeric o-rings, or various other materials, as dictated by the operating temperatures and pressures in the downhole environment. The annular seals **528**, **530** may have a metal cone sealable against a donut elastomer. Furthermore, the annular seals **528**, **530** may be face seals or shear seals. The annular seals **528**, **530** are adapted for sealably engaging inner walls **524**, **526** upon translatory movement of the piston **618** relative to the body **510**. FIG. **5**A shows the annular seal **530** engaging the inner wall **524** to close the first flowline **514**. Outer flanged portion **521**, **522** are affixed at the ends of the piston **518** for abutting the inner walls **524**, **526**.

The valve body **510** may also have a first hydraulic line **532** and a second hydraulic line **534** extending therefrom. The hydraulic lines **532**, **534** may be in communication with the directional unit, a pump, and/or any other device for creating differential pressure. Accordingly, differential pressure across the hydraulic lines **532**, **534** such as that provided by pressurized hydraulic fluid in a known manner, induces reciprocal translatory movement of the piston **518** within the passageway **512** of the body **510**. FIG. **5**A shows the valve system with the first flowline **514** in an open position, and the second flowline **516** in a closed position. Thus, in the position shown in FIG. **5**A, the first hydraulic line **532** has a higher pressure than the second hydraulic line **534**, resulting in the piston **518** being pressed against the first inner wall **524**. Thus, the position of the piston **518** may be controlled by the hydraulic lines **532**, **534** by increasing and decreasing the pressure within the lines. Thus, the valve **590** does not rely on pressure from formation fluid and/or the displacement unit to be toggled.

The valve **590** may further include a pair of coil springs **544**, **546** slidably disposed at least partially around a portion of the piston **518**. The coil springs **544**, **546** yieldably limit translatory movement of the piston **512** within the passageway **512**. Thus, increasing the pressure of the first hydraulic line **532** above that of the second hydraulic line **534** induces translatory movement of the piston **518** within the passageway **512** of the body **510** to one of two stop positions. In the stop position of FIG. **5**A, the outer flanged portion **522** of the piston **518** abuts a portion of the inner wall **526** of the valve body **510**. One having ordinary skill in the art will appreciate that, due to the spring loading on the piston **518**, the piston **518** may be positioned in the "no flow" condition. In "no flow" condition one of the annular seals **528**, **530** engage the inner walls **514**, **516** to close both the first flowline **514** and the second flowline **516**.

From the position of FIG. **5**A, the inner wall **526** constrains movement towards the coil spring **546**. Such movement occurs when the piston **518** is energized by the pressure of fluid provided to the hydraulic line **532**. The fluid pressure is increased on the first side **591** of the valve **590** until sufficient force is developed to overcome the bias of the coil spring **546**. In other words, the hydraulic pressure may move the plug **526** from the position of FIG. **5**A to the position of FIG. **5**B by compressing the coil spring **544** so that the coil spring **544** yields to such movement. The inner walls **524**, **526** may act as hard limits on the range of translatory movement by the piston **518**, and thus limit the range of yielding by the coil springs **544**, **546**. It will, therefore, be appreciated by one having ordinary skill in the art that a function of the coil springs **544**, **546** is to bias the piston **518** towards a position where one of the annular seals **528**, **530** engages the inner walls **524**, **526**. When the annular seals **528**, **530** engage the inner walls **524**, **526** the flowlines **514**, **516** close and prevent fluid flow through the valve passageway **512**.

FIG. **6** shows an embodiment of an active valve **690** with four hydraulic lines. As illustrated, this embodiment has four hydraulic lines **631**, **632**, **633**, and **634** on each side **691**, **692** of the piston **618**. Fluid may enter or exit the valve **690** through a first flowline **614** and/or a second flowline **616**. Fluid may also be communicated to a displacement unit via a third flowline **615**. Fluid may travel through a passageway **612** bored inside of the piston. Thus, fluid entering through the first flowline **614** may flow past a first inner wall **624** and the first end of the piston **618** into the passageway **612** of the piston **618**. From there, the fluid may exit the valve **690** through the third flowline **615**.

Movement of the piston **618** may be dictated by the increasing and/or decreasing of pressure in the hydraulic lines **631**, **633**. For example, hydraulic pressure may be increased in the hydraulic lines **631**, **633** to bias the piston towards an inner wall **626** to seal a second flowline **616**. A vacuum cavity **650** may be defined between the piston **618** and a body **610** of the valve **690**. The hydraulic lines **631**, **632**, **633**, **634** may be fluidly connected to the cavity **650** such that an increase and/or a decrease of pressure via the hydraulic lines **631**, **632**, **633**, **634** causes the piston **621** to move within the cavity **650**.

Elastomer donuts **628**, **630** may be provided on the inner walls **624**, **626** to engage end portions **621**, **622** of the piston **618**. Alternatively, a cone-shaped opening in the end portions **621**, **622** may engage a cone-shaped elastomer (not shown) extending from the inner walls **624**, **626** of the valve **690**.

Coil springs **644**, **646** may be provided within the valve **690** to aid in biasing the piston **618**. The coil springs **644**, **646** may act to move the piston **618** to an original position after the piston **618** has been moved to one side or another due to hydraulic pressure.

The preceding description has been presented with reference to present embodiments. Persons skilled in the art and technology to which this disclosure pertains will appreciate that alterations and changes in the described structures and methods of operation can be practiced without meaningfully departing from the principle and scope of the disclosure. Accordingly, the foregoing description should not be read as pertaining only to the precise structures described and shown in the accompanying drawings, but rather should be read as consistent with and as support for the following claims, which are to have their fullest and fairest scope.

In one example embodiment, a valve is disclosed comprising: a body defining a volume; at least two mud check valves in the body, a fluid passageway connecting the at least two mud check valves, a first flowline configured to transport a first portion of a fluid, a second flowline configured to transport a second portion of the fluid, wherein each of the first and second flowlines are configured to receive and discharge fluid from the passageway wherein the first flowline is configured to transfer the first portion of the fluid to a first portion of a downhole tool and wherein the second flowline is configured to transfer the second portion of the fluid to a second portion of the downhole tool.

In another example embodiment a valve for transporting a fluid, comprising: a body, a flowline, at least four hydraulic lines in the body, the hydraulic lines configured to transport the fluid, and a piston configured to move according to at least one of an increasing and decreasing pressure in two of the hydraulic lines, wherein the piston is configured to transport to a position to allow the fluid to exit the valve via the flowline.

Although exemplary systems and methods are described in language specific to structural features and/or methodological acts, the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described. Rather, the specific features and acts are disclosed as exemplary forms of implementing the claimed systems, methods, and structures.

What is claimed is:

1. A valve, comprising:
a body defining a volume;
at least two mud check valves in the body;
a fluid passageway connecting the at least two mud check valves;
a piston slidably disposed in the fluid passageway, wherein the piston is configured with a conduit portion comprising a bore therethrough the piston for conducting the fluid through the fluid passageway;
a first flowline configured to transport a first portion of a fluid;
a second flowline configured to transport a second portion of the fluid, wherein each of the first and second flowlines are configured to receive and discharge fluid from the passageway wherein the first flowline is configured to transfer the first portion of the fluid to a first portion of a downhole tool and wherein the second flowline is configured to transfer the second portion of the fluid to a second portion of the downhole tool;
a third flowline extending from the piston, wherein the piston comprises a passageway fluidly coupling the conduit portion of the piston and the third flowline;
a first hydraulic line configured to transport a hydraulic fluid; and
a second hydraulic line configured to transport the hydraulic fluid.

2. The valve according to claim **1**,
wherein the third flowline is configured to transfer fluid from a displacement unit to the valve.

3. The valve according to claim **1**, wherein the piston is configured between the first flowline and the second flowline.

4. The valve according to claim **1**, further comprising:
a pair of annular seals configured in the first flowline and the second flowline.

5. The valve according to claim **1**, further comprising:
a pair of coil springs slidably disposed at least partially around a portion of the piston.

6. The valve according to claim **1**, wherein the valve is configured for conveyance within a wellbore by at least one of a wireline or a drillstring.

7. A valve for transporting a fluid, comprising:
a body;
a first flowline configured to transport a first portion of a fluid;
a second flowline configured to transport a second portion of the fluid;
a third flowline;
at least four hydraulic lines in the body, the hydraulic lines configured to transport a hydraulic fluid;
a piston configured to move according to at least one of an increasing and decreasing pressure in two of the hydraulic lines, wherein the piston is configured to transport to a position to allow at least one of the first portion of the fluid to exit the valve via the first flowline or the second portion of the fluid to exit the valve via the second flowline, the piston is slidably disposed in a fluid passageway of the valve, the piston is configured with a conduit portion comprising a bore therethrough the piston for conducting the fluid through the fluid passageway, the third flowline extends from the piston, and the piston comprises a passageway fluidly coupling the conduit portion of the piston and the third flowline.

8. The valve according to claim **7**, wherein the valve is configured for conveyance within a wellbore by at least one of a wireline or a drillstring.

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